Kalanand Mishra

Research Associate & LPC Fellow for 2013, Fermilab CMS Center
MS 205, Wilson & Kirk Roads, Batavia, IL 60510
Tel.: (630) 840 - 2417, Fax: (630) 840 - 2194, email: kalanand@fnal.gov

Education

2008 — Ph.D. (Physics), University of Cincinnati, Cincinnati, Ohio, USA.
Thesis Title: "*Experimental Study of Three-body Cabibbo-suppressed D^0 Decays and Extraction of CP Violation Parameters*"
Thesis Advisers: Brian T. Meadows & Michael D. Sokoloff.

2000 — M.S. (Physics), Jawaharlal Nehru University, New Delhi, India.

Professional Experience

Feb '08 - Present — Research Associate at Fermilab, in the CMS experiment at the LHC.
Research interests: Higgs couplings, multi-boson production, triple/quartic gauge boson couplings, reconstruction of boosted signals – W, Z, Higgs, and top – using jet substructure. Have led team efforts of several key analyses for CMS.

- **Search for Higgs boson in H→WW:** The semileptonic H →WW channel is sensitive at high masses above the WW threshold and has the advantages of large branching fraction and a fully reconstructible invariant mass. Combining with WW leptonic channel result, we excluded the Standard Model (SM) Higgs boson in the mass range 130–600 GeV/c^2 at 95% confidence level. I led the semi-leptonic channel analysis effort within CMS. The results, available at this link are to be submitted for publication.
- **Anomalous bump in dijet mass spectrum in W+jj events:** I was the editor of the paper and co-led the CMS analysis effort on the study of dijet mass spectrum in W+2-jet events. With 5 fb^{-1} of 7 TeV data we excluded at 95% confidence level the anomalous bump near 150 GeV/c^2 reported by the CDF collaboration, and predicted by theoretical models such as technicolor and leptophobic Z$'$. The results are published. The analysis was featured in *Fermilab Today (August 31, 2012)*.
- **WW+WZ cross section and anomalous triple gauge couplings:** This was the first observation of diboson production in the semileptonic channel at the LHC. We also measured the sum of WW and WZ production cross sections and set stringent limits on anomalous triple gauge boson couplings, improving upon the LEP limit in some cases. I led this analysis effort using 5 fb^{-1} of 7 TeV data. The results are published.
- **Jet substructure:** We performed a comprehensive study of jet mass and substructure in dijet and W/Z+jets events using several jet algorithms (anti-k_T, Cambridge-Aachen), sizes (R= 0.5, 0.7, 0.8, 1.2), and grooming techniques (filtering, trimming, pruning). This constituted an important ground work for WH ($\to bb$) and high mass WW analyses using boosted jets. I was part of the 4-member team that carried out this analysis. The results, publicly available at this link, are to be submitted for publication.
- **W and Z boson inclusive cross sections at 7 TeV:** With better than 2% experimental uncertainty these measurements are the most precise at any hadron collider, and played a major role in physics commissioning of the CMS detector. I co-led the Z analysis team of 26 people. The results are published. The analysis was featured in *Fermilab Today (July 9, 2010)*.

In addition, I have contributed to the commissioning of physics objects for CMS.

- **Jet energy scale calibration:** I developed a framework to calibrate the jet energy scale (JES) using p_T-balance in Z+jet events. This contributed to achieving better than

3% precision in JES at CMS (published). Commissioning of jets in the first high-energy collisions at CMS was featured in *Fermilab Today (Feb 12, 2010)*.

- **Lepton calibration and efficiency:** I led the development of *tag & probe* framework to compute lepton efficiency using $Z \to \ell\ell$ decays. It has been used in a number of CMS published measurements, e.g., W, Z, $t\bar{t}$, and J/ψ cross sections. Team members who helped in electron commissioning were profiled in *Fermilab Today (Dec 10, 2010)*.

July '04 - Jan '08 Graduate student at U. Cincinnati in the *BABAR* experiment at SLAC. Helped with physics analysis and detector operations, developed particle ID.

- ***CP* asymmetry in charmed meson decays:** Measured decay rates, amplitudes, and *CP* asymmetries in rare neutral D meson decays to final states with three pions, or two kaons and a pion. Set upper limits at 1% level on *CP* violation in charm decays. Recently LHCb collaboration has found evidence for *CP* violation at the level of 0.5%.
- **Measurement of CKM phase γ:** Phase γ in the Kobayashi–Maskawa theory is the only source of *CP* violation in the quark sector of the SM. I performed an analysis of extremely rare B meson decays ($\mathcal{B} \sim 10^{-6}$) to D^0 or $\overline{D}^0$ meson, either of which decays to the same three-body final state. The *CP* violating angle γ appears in the interference between them ($B^\pm \to D^0 K^\pm \to \pi^+\pi^-\pi^0 K^\pm$ and $B^\pm \to \overline{D}^0 K^\pm \to \pi^+\pi^-\pi^0 K^\pm$). My analysis pioneered the technique of combining angular information provided by the quantum mechanical interference of amplitudes and the absolute decay rates.
- **Operation of Cherenkov detector & development of particle ID:** Served as Operations Manager of the Cherenkov detector during 2005–2006, responsible for overall daily operations. Developed the optimal performing particle-ID (called *KM selectors* after my initials) for kaon, pion, electron, and proton, which contributed to a 20% increase in B-meson reconstruction rate in many decay modes, and gave *BABAR* a significant advantage over their competitor *Belle* experiment.

Sep '03–June '04 Teaching Assistant, University of Cincinnati. Taught laboratory and recitation courses to engineering, medical, and physics undergraduates.

Technical accomplishments (hardware, software, calibration etc.)

- CMS:

  Developed *tag-and-probe* software to compute lepton efficiency. Measured electron efficiency, energy scale, resolution for CMS in the years 2008–2010. Contributed to jet commissioning and jet-ID development. Performed the jet energy scale calibration using Z+jet events in the years 2008–2011.

- *BABAR*:

  Developed optimal performing particle-ID for kaon, pion, electron, and proton. Developed framework to study particle-ID efficiency & fake-rate. Led the Cherenkov detector upgrade task during Summer 2005 shutdown, which included replacement of power-supply electronics and cooling system.

Leadership/Management

2010–present	Organize tutorials on physics analysis with jets for the *CMS Data Analysis School*.
2012–2013	Led BOOST 2012 subgroup charged with the study of jet grooming and pileup subtraction.
2011–2012	Co-led CMS analysis group on the study of the dijet mass spectrum in W+2 jet events.
2009–2012	Led development of *tag & probe* machinery to compute lepton efficiency in CMS.
2010–2011	Co-led CMS analysis team on the Z boson cross section measurement.
2008–2010	Responsible for electron efficiency measurements. My team provided tables of electron efficiency and data/MC scale factors to the CMS collaboration.

Teaching & Outreach

2010–2013 Taught a series of short courses on physics analysis with jets during *CMS Data Analysis School* in 2010, 2011, 2012, and 2013. Each course consists of a short exercise (3 hours) and a long exercise session (2 days). Participants are mostly grads and postdocs, and sometimes faculty/scientists. One such tutorial was featured in *Fermilab Today*, Feb 16, 2011.

2008–2012 Contributed to "Saturday Morning Physics". Started by Nobel laureate Leon Lederman in 1979, it is a series of nine lectures and tour visits given by Fermilab scientists with the purpose of increasing the understanding of modern physics among high school students.

2008–2012 Helped Fermilab-based CMS students with physics and data analysis.

2012 Answered public questions during "Ask-a-Scientist on Higgs!" outreach lectures at Fermilab on July 6 (by B. Christman, R. Roser, D. Green) and July 29 (by D. Lincoln).

2010 Gave tutorial in *Hadron Collider Physics Summer School* on data–theory comparisons.

2004–2007 Helped several students in getting up to speed. E.g., helped Rolf Andreassen (then a Cincinnati grad) with D^0–$\overline{D}^0$ mixing and operation of the Cherenkov detector, Christopher Morrison (now a grad at UC Davis) with undergraduate research project.

Mentoring

2013 Mentoring the following students at Fermilab LPC: Kevin Siehl (Wayne State Univ., topic: *Anomalous Gauge Couplings in WW*), Cristian Vega (Universidad San Francisco de Quito, Ecuador, *CMS Level-1 Upgrade*).

2012 Mentored the following students: Ajay Kumar (Delhi Univ. India, topic: *$H \to WW$ semi-leptonic*), Wei Zou (Peking Univ. China, *VBF Higgs in $H \to WW$*).

2012 Summer Mentored two undergraduate students: Geoffrey Fatin (Buffalo), Joseph Flanigan (Wisconsin, Milwaukee). Both came from the REU program at Wayne State sponsored by NSF. Geoffrey studied WWγ production. Joseph worked on boosted W reconstruction.

2011 Summer Mentored two undergraduate students: Kristina Krylova (Buffalo), Kellen McGee (Johns Hopkins). Both came from the REU program at Wayne State sponsored by NSF. They studied anomalous triple gauge boson couplings.

2009–2010 Mentored the following students: Mikhail Makouski (Kansas State, topic: *Z boson cross section*), Sunil Bansal (Panjab Univ. India, *jet energy calibration*), Mehmet Deliomeroglu (Bogazici Univ. Turkey, *electron efficiency as a function of jet multiplicity*), Kittikul Kovitanggoon (Texas Tech, *background estimation in W and top reconstruction*), David Bjergaard (Johns Hopkins, *tag & probe efficiency for leptons*).

Refereeing

2010–present Fermilab institutional review of CMS papers. In some cases led the group review.

2012–2013 CMS internal reviewer for "*Double Parton Scattering via W+di-jet*".

2010 CMS internal reviewer for "*Charged particle multiplicities in pp interactions at $\sqrt{s} = 0.9, 2.36,$ and 7.0 TeV*" (JHEP 1101:079, year 2011; arXiv:1011.5531).

Talks (since 2009)

Jan 2013 Invited talk at *Snowmass 2013: Energy Frontier Workshop on QCD Physics*, Fermilab. Title: "*Scale choices for complex processes*.

Jan 2013	HEP seminar at Iowa State University. Title: "*Pursuing Electroweak Symmetry Breaking at CMS using WW semi-leptonic final state*".
Dec 2012	Invited talk at US ATLAS Hadronic Final State Forum workshop, University of Chicago. Title: "*CMS measurements of jet structure and properties*".
Nov 2012	HEP seminar at Michigan State University. Title: "*Pursuing Electroweak Symmetry Breaking at CMS using WW semi-leptonic final state*".
Nov 2012	HEP seminar at Wayne State University. Title: "*Pursuing Electroweak Symmetry Breaking at CMS using WW semi-leptonic final state*".
Oct 2012	Physics colloquium, Florida Tech. Title: "*Discovery or Illusion: The Tale of a Tantalizing Bump*".
Sept 2012	Invited talk at *Workshop on electroweak corrections for LHC physics*, IPPP Durham (UK). Title: "*Electroweak measurements at CMS*".
Sept 2012	Joint Experimental-Theoretical (Wine & Cheese) Seminar at Fermilab, Title: "*Search for New Physics in Diboson Events at CMS*".
Aug 2012	Invited talk, *QCD@LHC 2012*, MSU. Title: "*W/Z+jets (incl. heavy flavor) at LHC*".
July 2012	BOOST 2012, Valencia, Spain. Title: "*Performance of jet substructure with pileup*".
July 2012	ICHEP 2012, Melbourne, Australia. Title: "*WW, WZ and ZZ production at CMS*".
Jan 2012	Physics colloquium, U. Cincinnati. Title: "*Endgame for the Higgs boson?*".
Oct 2011	Invited talk, *Lattice Meets Experiment 2011: Beyond the Standard Model*, Fermilab. Title: "*Technicolor searches at colliders*".
Aug 2011	APS (DPF), Providence, RI. Title: "*Study of Diboson Production at CMS*".
2009–2011	Periodically presented CMS/LHC status report in Fermilab *All Experimenters' Meeting* (organized by Fermilab directorate), most recently *in August 2011*.
May 2011	HEP seminar, Univ. Oregon. Title: "*CMS Electroweak and Higgs Results & Prospects*".
May 2011	Invited talk, *EWSB11*, U. Wisc., Madison. Title: "*CMS Higgs Search Results & Prospects*".
Mar 2011	HEP seminar, U. Cincinnati. Title: "*W and Z Physics at CMS*".
Dec 2010	Conference on First LHC Data, U. Mich., Ann Arbor. Title: "*W and Z Physics at CMS*".
Aug 2009	JTerm, Fermilab. Title: "*Physics Objects: How to Extract Clean Objects Starting with Jets*".
May 2009	U. Chicago Enrico Fermi Inst. Title: "*Jet Energy Corrections at CMS*".

More than 350 presentations in CMS internal meetings since 2008 (accessible to CMS members): http://indico.cern.ch/search.py?p=Kalanand+Mishra&categId=2l76

Publications

- I am a primary author and led key parts of the analysis effort in the following CMS results:
  [1] "*Study of the dijet mass spectrum in pp to W + jets events at* $\sqrt{s} = 7$ *TeV*", S. Chatrchyan *et al.* [CMS], Phys. Rev. Lett. **109**, 251801 (2012), arXiv:1208.3477. I was the editor for the paper and wrote the drafts.

  [2] "*Measurement of the sum of WW and WZ production with W+dijet events in pp collisions at* $\sqrt{s} = 7$ *TeV*", S. Chatrchyan *et al.* [CMS], Eur. Phys. J. **C73**, 2283 (2013), arXiv:1210.7544. I was the editor for the paper and wrote the drafts.

[3] "*Search for the Standard Model Higgs boson in the H to WW to $\ell\nu jj$ decay channel at the LHC*", CMS-HIG-12-046 (2012), http://cdsweb.cern.ch/record/1494573. "*Search for the Standard Model Higgs boson in the H to WW to $\ell\nu jj$ decay channel at $\sqrt{s}$ = 8 TeV*", CMS-HIG-12-021 (2012), http://cdsweb.cern.ch/record/1460660. "*Search for the Standard Model Higgs boson in the H to WW to $\ell\nu jj$ decay channel at $\sqrt{s}$ = 7 TeV*", CMS-HIG-12-003 (2012), http://cdsweb.cern.ch/record/1449158. I was the editor for all three public docuements. A publication on high mass Higgs searches in WW and ZZ decay modes is to be submitted to *Eur. Phys. J. C.*

[4] "*Measurements of Inclusive W and Z Cross Sections in pp Collisions at $\sqrt{s} = 7$ TeV*", S. Chatrchyan *et al.* [CMS], JHEP **1110**, 132 (2011), arXiv:1107.4789.

[5] "*Determination of Jet Energy Calibration and Transverse Momentum Resolution in CMS*", S. Chatrchyan *et al.* [CMS], JINST **6**, P11002 (2011), arXiv:1107.4277.

[6] "*Measurements of Inclusive W and Z Cross Sections in pp Collisions at $\sqrt{s} = 7$ TeV*", V. Khachatryan *et al.* [CMS], JHEP **1101**, 080 (2011), arXiv:1012.2466.

- Directly contributed to the following and am listed as an author in the CMS internal note:

[1] "*Search for Dijet Resonances in 7 TeV pp Collisions at CMS*", V. Khachatryan *et al.* [CMS], Phys. Rev. Lett. **105**, 211801 (2010), arXiv:1010.0203.

- A primary author of the following analyses performed for my Ph.D. thesis:

[1] "*Search for CP Violation in Neutral D Meson Cabibbo-suppressed Three-body Decays*", B. Aubert *et al.* [BABAR], Phys. Rev. D **78**, 051102 (2008), arXiv:0802.4035. I was the editor for the paper and wrote the drafts.

[2] "*Isospin analysis of D^0 decay to three pions*", M. Gaspero, B. Meadows, K. Mishra, and A. Soffer, Phys. Rev. D **78**, 014015 (2008), arXiv:0805.4050.

[3] "*Experimental Study of Three-body Cabibbo-suppressed D^0 Decays and Extraction of CP Violation Parameters*", K. Mishra, Ph.D. thesis, SLAC-Report-893 (2008).

[4] "*Constraints on CP violation parameters with a Dalitz plot analysis of $B^\pm \to D_{\pi^-\pi^+\pi^0}K^\pm$*", B. Aubert *et al.* [BABAR] , Phys. Rev. Lett. **99**, 251801 (2007), arXiv:hep-ex/0703037.

[5] "*Charmed Meson Dalitz Plot Analysis at BABAR*", K. Mishra, *Proceedings of the XII International Conference on Hadron Spectroscopy*, Frascati Physics Series Vol. 46 (2007), 967, arXiv: 0711.1544.

[6] "*Amplitude Analysis of the Decay $D^0 \to K^-K^+\pi^0$*", B. Aubert *et al.* [BABAR], Phys. Rev. D **76**, 011102 (2007), arXiv:0704.3593. I was the editor for the paper and wrote the drafts.

[7] "*Precise Branching Ratio Measurements of the Decays $D^0 \to \pi^-\pi^+\pi^0$ and $D^0 \to K^-K^+\pi^0$ Relative to the $D^0 \to K^-\pi^+\pi^0$ Decay*", B. Aubert *et al.* [BABAR], Phys. Rev. D **74**, 091102 (2006), arXiv:hep-ex/0608009. I was the editor for the paper and wrote the drafts.

- Listed as an author for several hundred peer-reviewed journal articles whose scientific results were obtained in collaboration with others. Complete list: http://inspirehep.net/author/K.Mishra.1